A Performance Measurement Tool (PMT) to Control Maintenance-Associated Infections

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Table 1: Categorisation of the CSFs and Performance Measures According to the BSC Perspectives

BSC Perspective (A)	CSFs (B)		Performance Measures (C 1 - 67)
A. Internal Business Perspectives	1. Liaison and Communication with ICT (6)		1. Early consultation and authorisation from the Infection Control Team before commencement of any maintenance work posing risk of HAIs.
			2. Seek the advice of the Infection Control Team (ICT) on such matters concerning infections.
			3. Liaise with person in charge of area where maintenance is to be carried out.
			4. Put a system in place for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.
			5. Establish communication channel between maintenance staff and contracted staff.
			6. Regularly meet with Infection Control and Clinical representatives to ensure maintenance processes complement clinical care.
	2. Infection Control Practices (20)	*Cleaning Requirements (8)*	7. Provide active means to prevent airborne dust from dispersing into high-risk patient areas.
			8. Ensure compliance with hand hygiene whilst working in clinical areas.
			9. Ensure compliance with use of personal protective equipment as required.
			10. Report any injury, especially if ‘sharp’-related; cover wounds or sores.
			11. Maintenance staff not to work in clinical areas if any symptoms of infection i.e. diarrhoea or vomiting (seek advice from the ICT).
			12. Conduct maintenance work in a manner that eases cleaning.
			13. Provide temporal hand-washing facilities for maintenance staff working in high-risk patient areas.
			14. Wash and sanitize drainage equipment after use.
		Administrative Requirements (8)	*15.* Inform Charge Nurse before commencement of maintenance work.
			16. Ensure in–house staff and contractors work to same clear guidelines.
			17. Maintain and review infection control policies and procedures.
			18. Before commencement of maintenance work, obtain infection control permit and assess patients for risk of maintenance-associated HAIs.
			19. Develop a work culture that supports prioritization of maintenance work in infection control.
			20. Put in place safe working system for maintenance staff in infection prevention.
			21. Pre-employment health check and immunization program for all in-house and contracted maintenance staff.
			22. Have agreed HAI plan to control all contract works on site. Review plan annually to monitor level of compliance and provide annual improvement action plan based on previous year’s findings.
		Transport Requirements (4)	23. Ensure health and safety signage used.
			24. Contain construction waste before transport in tightly covered containers.
			25. Transport clean and sterile equipment to storage areas via route that minimises contamination.
			26. Redirect pedestrian traffic from work areas.
	3. SLA Agreement (8)		27. Ensure contractors take responsibility for any unsafe equipment or practice posing risk of infection.
			28. Contractors to have safe record-keeping and adhere to mandatory code of conduct in infection control.
			29. Contracted workers to attend all mandatory induction and training in infection control.
			30. Contractor to have arrangements in place to respond to emergency calls.
			31. Changes in assets and legislation to be taken into account when renewing contracts.
			32. Contractor to have procedures in place to supervise maintenance work and variables, i.e. spares, etc.
			33. Contractors to be selected on basis of strong technical, resource, managerial and communication capabilities.
			34. Customer satisfaction survey to be part of service level agreement with contractors.
	4. Maintenance Strategies (8)		*35. Water safety plan to be developed and reviewed annually by maintenance and Infection Control Teams to identify, manage and control risks of waterborne infections associated with maintenance activities.*
			36. Establish system for ensuring timely execution of all planned maintenance work posing risk of infection.
			37. Building defects to be prioritised and dealt with in time-critical period to minimise the risk of HAIs.
			38. Ensure monitoring of effectiveness of all critical maintenance equipment/assets that may cause HAIs.

			39. Computer-based maintenance system (i.e. reliability-centred maintenance) to be implemented to coordinate all maintenance work.
			40. Computer system to promote mobility and allow maintenance staff to access all necessary information and communicate back to coordinators when job cannot be completed first time.
			41. Implement daily check of all critical maintenance systems posing the risk of HAIs
			42. Categorize hospital assets, and maintenance equipment into significant and non-significant items in infection control.
	5. Risk Assessment (4)		43. All stakeholders (i.e. ICT) to be involved in in risk identification and response.
			44. Education and clear lines of individual responsibility to be provided for staff in managing risk of maintenance-related infections.
			45. Establish process for reporting, managing and analysing complaints and incidents in infection control.
			46. Recognised risk assessment tool (i.e. infection control risk assessment – ICRA) to be used to match level of risk associated with maintenance work.
B. Financial	**6. Maintenance Resource Availability (7)**		47. Adequate resources to be provided for mandatory and operational compliance by healthcare maintenance unit in infection control.
			48. Processes to be established to control introduction of new equipment/fabric that can be maintained efficiently and reduce risk of HAIs.
			49. Condition of hospital building services and infrastructure to be reviewed to feed into investment program.
			50. Risk assessment to be used in maintenance-associated HAIs to direct maintenance resources to highest risk activities.
			51. Quality maintenance materials and products to be purchased from reliable suppliers.
			52. HMU in the IC Department to be involved in purchase of maintenance materials and products.
			53. Monthly review of expenditure against budget in IC to be conducted.
C. Innovation and Learning	**7. Staff Education (8)**	***Training (4)***	54. All maintenance staff to be provided with information on statutory and technical guidance on infection control.
			55. Skilled and competent staff to be employed to ensure safe and efficient maintenance operations.
			56. Annual review of staff training to be conducted.
			57. Site induction on infection control to be conducted within a few weeks of employment.
		Development (4)	*58.* Maintenance department to be represented in infection prevention and control and on risk/governance committees
			59. Education to be provided for maintenance staff on assessing and managing risk of maintenance-associated hospital-acquired infections (HAIs)
			60. Briefings and appraisal schemes in infection control to be introduced for maintenance staff.
			61. Initiatives to be introduced for granting equal access to staff and improve working life.
D. Customer Satisfaction	**8. Customer Satisfaction (6)**		*62. Records to be kept of number of completed maintenance jobs that failed to meet required standard in infection control.*
			63. System to be implemented to review and analyse complaints about maintenance services and to recommend improvement.
			64. Speed of responses to maintenance requests to be measured.
			65. Number of maintenance products that do not conform to request to be measured.
			66. Speed of response to complaints about completed maintenance work to be measured.
			67. Complaint boxes/leaflets to be made available to enable people to raise issues related to quality of maintenance services.

Table 2: Establishing the Level of Importance of CSFs and Performance Measures

(A) BSC Perspective	(B) CSFs	(C) Performance Measures	(D) Mean Score	(E) Rank	Mean scales and weight (W)					Weighted Mean	
					Zone I.	Zone II.	Zone III.	Zone IV.	Zone V.	Total (E) Σ(C × W)/C	Level of Importance of CSF
					≤ 3.82 to ≥ 4	≤3.64 to >3.82	≤3.46 to >3.64	≤3.28 to >3.46	< 3.28		
					W = 4	W = 3	*W = 2*	*W = 1*	*W = 0*		
Internal Business Processes	**1. Liaison and Communication with the Infection Control Team (ICT)**	**C – 1**	4.0000	1	**2(4) = 8**	**1(3) = 3**	**1(2) = 2**	**2(1) = 2**	**-**	**15/6**	**2.5**
		C – 2	3.9333	3							
		C – 3	3.7333	13							
		C – 4	3.5333	26							
		C – 5	3.3333	46							
		C – 6	3.3333	46							
	2. Infection Control Practices	**N = 20**			**4(5) = 20**	**3(3) = 9**	**5(2) = 10**	**4(1) = 4**	**4(0) = 0**	**43/20**	**2.15**
	– ***Cleaning Requirements***	**C – 7**	4.0000	1	*3(4)= 12*	*2(3)* = 6		*1(1)* = 1	*2(0)* = 0	*19/8*	*2.375*
		C – 8	3.8667	7							
		C – 9	3.8667	7							
		C – 10	3.6667	17							
		C – 11	3.6429	20							
		C – 12	3.4000	38							
		C – 13	3.2000	56							
		C – 14	3.2000	56							
	– ***Administrative Requirements***	***C – 15***	3.9333	3	*1(4)* = 4	*1(3)* = 3	*4(2)* = 8	*1(1)* = 1	*1(0)* = 0	*16/8*	*2*
		C – 16	3.8000	11							
		C – 17	3.6000	21							
		C – 18	3.6000	21							
		C – 19	3.5833	25							
		C – 20	3.5333	26							
		C – 21	3.4286	36							
		C – 22	3.0000	61							
	– ***Transport Requirements***	**C – 23**	3.4667	31	-	-	*1(2) = 2*	*2(1)* = 2	*1(0)* = 0	*4/4*	*1*
		C – 24	3.4000	38							
		C – 25	3.4000	38							
		C – 26	3.2000	56							
	3. SLA Agreement	**C – 27**	3.7692	12	**-**	**3(3) = 9**	**2(2) = 4**	**2(1) = 2**	**1(0) = 0**	**15/8**	**1.875**
		C – 28	3.7333	13							
		C – 29	3.7143	15							
		C – 30	3.5333	28							
		C – 31	3.4667	31							
		C – 32	3.3333	46							

		C – 33	3.2857	52							
		C – 34	2.9333	65							
	4. Maintenance Strategies	**C – 35**	3.9167	6	**1(4) = 4**	**1(3) = 3**	**1(2) = 2**	**2(1) = 2**	**3(0) = 0**	**11/8**	**1.375**
		C – 36	3.7143	15							
		C – 37	3.6000	21							
		C – 38	3.4000	38							
		C – 39	3.4000	38							
		C – 40	3.3333	46							
		C – 41	3.2667	54							
		C – 42	2.9993	64							
	5. Risk Assessment	**C – 43**	3.6667	17		**1(3) = 3**	**1(2) = 2**	**1(1) = 1**	**1(0) = 0**	**6/4**	**1.5**
		C – 44	3.4667	31							
		C – 45	3.4000	38							
		C – 46	3.2000	56							
Financial	**6. Maintenance Resource Availability**	**C – 47**	3.9333	3	**3(4) = 12**	**-**	**-**	**2(1) = 2**	**2(0) = 0**	**14/7**	**2**
		C – 48	3.8667	7							
		C – 49	3.8667	7							
		C – 50	3.4545	35							
		C – 51	3.3333	46							
		C – 52	3.2500	55							
		C – 53	2.6000	67							
Innovation and Learning	**7. Staff Training and Development**	**N = 8**				**1(3) = 3**	**2(2) = 4**	**4(1) = 4**	**1(0) = 0**	**11/8**	**1.4**
	– ***Training***	**C – 54**	3.6000	*21*	-	-	*2(2)* = 4	*2(1)* = 2	-	*6/4*	***1.5***
		C – 55	3.5000	*29*							
		C – 56	3.4000	*46*							
		C – 57	3.3333	*38*							
	– ***Development***	**C – 58**	3.6667	*17*	-	*1(3)* = 3	-	*2(1)* = 2	*1(0)* = 0	*5/4*	***1.3***
		C – 59	3,4286	*36*							
		C – 60	3.2857	*52*							
		C – 61	3.0000	*61*							
Customer Satisfaction	**8. Customer Satisfaction**	**C – 62**	3.5000	29	**-**	**-**	**2(2) = 4**	**1(1) = 1**	**3(0) = 0**	**5/6**	**0.8**
		C – 63	3.4667	31							
		C – 64	3.4000	38							
		C – 65	3.1333	60							
		C – 66	3.0000	61							
		C - 67	2.8667	62							
Total		**67**			**10 (14.9)**	**9 (13.4%)**	**11(16.4%)**	**23 (34%)**	**14 (20.8)**	**-**	

Table 3: Performance Measurement Tool (PMT) in HM in IC (An Exemplar)

Mean Zones	Selected Performance Measures (P)	Performance Level Rating (L) 1	2	3	4	5	Weighting (W)	Weighted Score WS = (L×W)	Performance Score 1- for each Performance Measure $\frac{(L)}{(5)} \times 100$	Performance Score 2- for each Individual Mean Zone	Performance Score 3 – Considering all Mean Zones	Overall Performance of the HMU in HAI
WS A ≤ 3.82 to ≥ 4	1. Implement early consultation and authorization from the Infection Control Team before commencement of any maintenance work posing risk of HAIs.				4		4	16 (WS_1)	80%	$\frac{(WS_1+WS_2+WS_3)}{N(P_A) \times (L*W)} \times 100$ $\frac{16+12+12}{3\ (20)} \times 100$ **= 66.6%**	$\frac{\Sigma (WS_A)}{\Sigma (WS_A + WS_B + WS_C + WS_D)} \times 100$ $\frac{(16+12+12)}{60+30+30+10} \times 100$ $\frac{4000}{130}$ **= 30.77 %**	$\Sigma (WS_A + WS_B + WS_C + WS_D)$ 30.77 + 16.15 + 15.38 + 3.08 **= 65.38%** **Performance Status: GOOD**
	2. Provide active means to prevent airborne dust from dispersing into high-risk patient areas.			3			4	12 (WS_2)	60%			
	3. Water safety plan to be developed (and reviewed annually) by maintenance and Infection Control Teams to identify, manage and control risks of waterborne infections associated with maintenance activities.			3			4	12 (WS_3)	60%			
WS B ≤3.64 to >3.82	4. Ensure in–house staff and contractors work to same clear guidelines.				4		3	12 (WS_4)	80%	$\frac{(12+9)}{2\ (15)} \times 100$ **= 70%**	$\frac{(12+9)}{130} \times 100$ **= 16.15 %**	
	5. Contracted workers to attend all mandatory induction and training in infection control.			3			3	9 (WS_5)	60%			
WS C ≤3.46 to >3.64	6. Put a system in place for maintenance staff to liaise with domestic staff regarding cleaning during and on completion of work.	1					2	2 (WS_6)	20%	$\frac{(2+10+8)}{3\ (10)} \times 100$ **= 66.66 %**	$\frac{(2+10+8)}{130} \times 100$ **= 15.38 %**	
	7. System to be implemented to review and analyse complaints about maintenance services and to recommend improvement.					5	2	10 (WS_7)	100%			
	8. Skilled and competent staff to be employed to ensure safe and efficient maintenance operations.				4		2	8 (WS_8)	80%			
WS D ≤3.28 to >3.46	9. Regularly meet with Infection Control and Clinical representatives to ensure maintenance processes complement clinical care.	1					1	1 (WS_9)	20%	$\frac{(1+3)}{2\ (5)} \times 100$ **= 40 %**	$\frac{(1+3)}{130} \times 100$ **= 3.08 %**	
	10. Site induction on infection control to be conducted within a few weeks of employment.			3			1	3 (WS_{10})	30%			
Weighted Score for all Mean Zones								**85**				

1. Introduction

The term Hospital-acquired infections (HAI) usually means infections that were neither present nor incubating when a patient, visitor or hospital staff member enters the hospital (National Audit Office (NAO), 2004). HAIs are a major problem to healthcare institutions throughout the world. According to estimates by the World Health Organisation, out of every one hundred patient admitted to hospital at any one time, seven in the developed and ten in the developing countries acquire at least one type of HAI (WHO, 2002). The European Centre for Disease Control and Prevention estimates that about 3.2 million patients in European acute care hospitals acquire HAIs every year (ECDC, 2013).

Before the introduction of mandatory surveillance, about 9% of inpatients in the UK acquired an HAI during their stay in hospital (Parliamentary Office of Science and Technology, 2005). However, since the introduction of mandatory surveillance in 2001, there has been a steady fall in the rate of Meticilline-resistant *Staphylococcus aureus* (MRSA) and *Clostridium difficile* (*C. difficile*) in England (Health Protection Agency (HPA), 2012). According to HPA (2009), MRSA bloodstream infections in England fell from 6,383 in 2006/07 to 2,933 in 2008/09 (a 54% reduction). Equally, the rate of *C. Difficile* fell from 55,499 in 2007/08 to 36,097 in 2008/09 (a 35% reduction). By reducing the rate of MRSA and *C. Difficile*, the NHS has been able cut costs in areas such as drug therapy, hospital re-admissions and ward closures.

Apart from those infections i.e. MRSA and *C. Difficile*, which are under mandatory surveillance, there is no evidence suggesting that rates of HAIs are falling. The BBC (2014) estimates that about 300,000 inpatients acquire an HAI each year - that is, one in every 16 patient being treated by the NHS. Figures released by ECDC (2013) show that the rate of *C. difficile* in England is higher than in the Netherlands, France, Spain and Italy. The deputy chief executive of the National Institute for Health and Clinical Excellence noted, "*It is* *unacceptable that infection rates are still so high in within the NHS"* (BBC, 2014). These figures could even be higher, as estimates of HAI in England do not take into full account HAI acquired after a patient has been discharged from hospital. According to the NAO (2000), about 50-70% of surgical wound infections occur post-discharge. Apart from prolong a stay in hospital, HAIs may also worsen the patient's underlying condition, inflict pain and bring unnecessary misery to family members and friends.

In addition to the human cost of HAI is the financial cost, which has raised the concern of health authorities and the public. The total cost of HAI to the NHS is about £986.36 million annually, with the larger part of the money £930.62 million being incurred by the in-patient services (NAO, 2000). The remaining £55.74 million is incurred post discharge by GPs, outpatient consultants and district nursing services. The cost of treating a patient who acquires one or more HAI whilst receiving treatment at the hospital is 2.8 times greater than for a patient without an infection. This additional cost is incurred directly by the NHS on such issues as increased length of hospital stay, additional antibiotic therapy, repeated surgery, food, testing (laboratory and radiography) etc. On average, a patient infected with HAI cost the NHS an additional £2,917 to treat. Costs generally range from £1,222 for urinary tract infections to £6,209 for blood infections (NAO, 2000). In 2007-8, the NHS spent at least £20 million and £75 million treating patients with MRSA and C. difficile infections respectively (NAO, 2009). Litigation cost is also set to grow following successful legal claims for compensation after acquiring HAI.

Despite the huge cost of HAIs, through better infection control practices, the NHS could reduce the incidence of HAI by up to 15-30% (NAO, 2004). Any reduction in the cost of HAI in the NHS could free up additional cash, which could then be used in the provision of alternative healthcare related priorities. According to the National Institute for Health and Clinical Excellence, every 5% reduction in the rate of MRSA and *C. Difficile* could result in a cost saving of about £4.9 million annually to the NHS (NICE, 2011).

All this suggests that healthcare officials need to adopt a holistic approach that focuses on tackling the root causes of hospital-acquired infections. Usually these causes take one of two forms, i.e. clinical or non-clinical. Presently, it appears that insufficient attention is paid to the non-clinical causes of HAIs in hospitals. The non-clinical causes of HAIs are normally associated with poor performance on the part of healthcare facilities management services in infection control (IC). Such services include for example cleaning (to avoid contamination of equipment and the built environment), catering (to avoid food contamination), building maintenance (to avoid cross-infection), and practices of healthcare facilities management workers (to avoid contact transmission) (WHO, 2002). The two areas that seem to attract the most attention from healthcare authorities are cleaning and catering. This is because cleaning is often seen by the public and trade unions (i.e. Unison) as the cause of infections, i.e. MRSA and *C. Difficile*. The same is true of catering, which is often blamed for food poisoning outbreaks such as food-borne salmonellosis at the Stanley Royd Hospital.

Apart from cleaning and catering, however, healthcare facilities management services are treated as though they have no connection with IC. Yet epidemiological evidence gathered in this research also implicates healthcare maintenance in the incidence of HAIs in hospitals. In the next section, the significance of healthcare maintenance in IC is examined in depth. For reasons of space, this research focuses exclusively on healthcare maintenance, and particularly on performance measurement in this area. To present this, the paper is divided into two main sections. In the first section, the rationale for the selection of healthcare maintenance is provided; in the second section, the focus is on the development of a performance measurement tool (PMT) in healthcare maintenance in IC.

1.1 Maintenance services in the control of HAIs

Without an efficient and well-coordinated maintenance function, it is unlikely that buildings will function properly. Maintenance can prevent disruption of core business activities that may have cost implications and undesirable outcomes (e.g. customer dissatisfaction, non-compliance with legal requirements, health and safety problems, increased energy consumption and damage to the environment, etc. (Lam, 2007). The Yeovil District Hospital NHS (2009, p.3) defines healthcare maintenance as the "*combination of all technical and administrative actions, including supervision actions, intended to keep an item in, or restore it to, a state in which it can perform a required function. Given due consideration to viability and economic financial responsibilities*".

The nature of the business of hospitals requires that the healing indoor environment "*considers infection control safety for patients and staff as an added factor for a safe environment of care*" (Streifel, 2005, p.1). Evidence gathered from the literature shows a causal link between maintenance works carried out in and around hospitals and HAI. In hospitals, maintenance work has been implicated in the spread of conidia through the airborne route (Hoffman *et al.,* 1999). According to Tabbara and Jabarti (1998), old hospitals (termed 'sick' buildings) are more likely to harbour spores of fungi, including *Aspergillus*. Although fungi (Aspergillum species) are naturally occurring, ubiquitous and a natural part of the biological ecosystem (Burrill 2008), they pose a significant risk to patients whose immunity has been compromised because of age, underlying illness or medical or surgical treatment (Joseph 2006). Invasive aspergillosis affects ≤14 per cent of lung transplant recipients and ≤ 28 per cent of patients who have undergone allogeneic hematopoietic stem cell transplantation (Wald *et al.*, 1997). In Canada alone, about 50% of negative patient outcomes (including several deaths) have been caused by *Aspergillus fumigatus* (Health Canada, 2001, cited in Burrill, 2008). Such figures have led the Centres for Disease Control and Prevention (2005, as cited in Burrill, 2008: p. 56) to state that "*HAIs may be associated with dust exposure during building renovation* [maintenance] *or construction*".

Despite all this, it appears the issue of maintenance-associated infections (infections caused by maintenance activities in hospitals) has failed to attract the full attention of healthcare officials. As a result, the healthcare maintenance department and NHS Trust maybe pursuing different objectives in IC. Lee and Scott (2008) blame this on maintenance staff for relying too much on their technical experience and skills and not connecting with core business objectives. Others have also attributed this to confusing and piecemeal core business objectives that pay little attention to building maintenance. According to Hicks (2004), some healthcare establishments have not even realised the benefits of having written missions, visions, goals and objectives for their maintenance departments. Those written statements that are in place have focus mainly on cost (Lee and Scott, 2008). Such a culture can create a dysfunctional maintenance department that has no business orientation.

Because top managers generally lack an understanding of the science of maintenance, they appear to rely on the old tenet *'if it isn't broke, don't fix it'* (Chalifoux and Baird, 1999). As a result, they are often reluctant to allocate a sufficient budget to allow the maintenance department carry out comprehensive maintenance strategies. Whilst slashing the budget allocated to strategies such as preventive maintenance may offer short-term cost savings, it may increase the probability of failures. In the words of Thun (2004, cited in Bivona and Montemaggiore, 2005), this creates a vicious cycle: *"'Repairs eat up Prevention' results in a situation with many unexpected machine breakdowns and an overloaded maintenance department".*

Following criticisms of the performance of healthcare maintenance services in IC, some NHS hospitals have started formulating policies to minimise the risk of maintenance-associated HAIs. However, there appears to be wide variation in the number of IC issues addressed in healthcare maintenance policies across the NHS. In addition, little is known about whether these policies are effectively implemented and realised by healthcare maintenance departments. According to Healthcare Facilities Scotland (2007), there is a problem with the effective dissemination and implementation of existing policies and guidelines in a logical and accessible form to all involved in the control of HAI in the NHS.

Instead of focusing on the core business issues of the NHS (i.e., infection control), most healthcare maintenance managers spend considerable time and energy focusing on reactive measures to reduce costs

The above discussion clearly highlights the consequences of a lack of performance measurement in healthcare maintenance in IC. Generally, healthcare facilities management services like maintenance have a poor understanding of performance measurement and its application to IC (Liyanage and Egbu, 2005). Even where attempts have been made to measure performance in relation to infection control, they use only a limited number of indicators and measures. The purpose of this paper is therefore to fill this gap by developing a tool that measures performance adequately in healthcare maintenance in IC. As outlined in the next section, this was achieved using a three-step process.

2. The process adopted for developing a performance measurement tool (PMT)

It is clear from the above discussion that improving the performance of the healthcare maintenance department in IC will help the NHS reduce its current rate of HAIs. As stated earlier, a Performance Measurement Tool was developed using a three-step process:

Step 1. Identification of the critical success factors (CSFs) and performance measures in healthcare maintenance in IC. Here, a brief discussion is provided about the methodology, i.e. the literature reviews, grounded theory and the balanced scorecard (BSC) used to identify the CSFs and performance measures. The BSC is described in section 2.1.

Step 2. Ranking the CSFs according to their importance in IC. This was achieved on the basis of the results of a three-round Delphi study (refer to section 2.2).

Step 3. Developing a PMT in healthcare maintenance to measure performance in IC. Here weightings were assigned to the performance measures identified through the

Delphi study, and formulae established for calculating the performance of the healthcare maintenance department in IC at various levels.

2.1 Step 1 - Identifying the CSFs and Performance Measures in IC

Today's business environment is much more dynamic than it used to be many years ago. Besides stiff competition, organisations also face the challenges of meeting the needs of their stakeholders. Healthcare maintenance departments in the NHS cannot ignore such challenges. The widespread mechanisation and automation of companies has reduced the number of production personnel, and increased the capital employed in production equipment. Consequently, the number of maintenance staff has grown alongside the proportion of total operating costs spent on maintenance. The technological needs arising from a better understanding of the causes of diseases, together with an ever-increasing number of susceptible patients, have revolutionised the process of healthcare maintenance. Today's healthcare maintenance has to grapple with complex electrical, heating, plumbing, air conditioning, mechanical and medical equipment and devices in order to meet the needs of the NHS.

An important step towards meeting some of these challenges is measuring the performance of the healthcare maintenance department in IC. In this paper, it is argued that this should be achieved through the development of a PMT. According to Tsang (1998, p. 87), "*considering maintenance a purely tactical matter is myopic*". The first step in the development of the PMT is the identification of the CSFs and performance measures in healthcare maintenance in IC. CSFs are *"…key areas of performance that are essential for the organisation to accomplish its mission* [goals, objectives, or projects]" (Caralli, 2004, p. 2). Performance measures on the other hand are *"… specific standards which allow the calibration of performance for each critical success factor, goal, or objective*" (Bullen and Rockart, 1981, p. 8). CSFs and performance measures can provide healthcare maintenance managers with valuable information to drive performance in healthcare maintenance in IC effectively.

An in-depth review of relevant research materials was conducted to identify the CSFs and performance measures in healthcare maintenance in IC. Strict criteria were adopted in the selection process. The research materials needed to contain rich information concerning the control and prevention of maintenance-associated HAIs in hospitals. In total, the literature review resulted in the selection of 27 key IC documents: seven government documents, 10 healthcare maintenance policies and 10 clinical peer-reviewed journals.

Grounded theory analyses of the 27 selected documents resulted in the identification of 56 performance measures in healthcare maintenance in IC. In contrast to the usual treatment of this topic elsewhere, these performance measures were categorised under eight CSFs. According to Lavy *et al*. (2010), little attempt has been made in facilities management to group performance measures according to criteria that allow interrelationships to be properly understood and analysed. As shown in Table 1, the eight CSFs in healthcare maintenance in IC are Liaison and Communication with the Infection Control Team, Infection Control Practices, Maintenance Strategies, Risk Assessment, Maintenance Resource Availability, Staff Education and Customer Satisfaction. For the purpose of clarity, some of the CSFs were sub-divided. For example, the 'Infection Control Practices' was divided into Cleaning, Administrative and Transport Requirements (see Table 1).

Traditionally, most organisations restrict performance measurement in maintenance to the tracking of direct costs or their surrogates such as the headcount of tradesmen (Tsang, 1998). In order to drive overall performance across the healthcare maintenance department, managers must also focus on non-financial measures. Therefore, the 56 performance measures and eight CSFs were further categorised into the four perspectives of the (BSC): Financial, Internal Business Processes, Innovation and Learning, and Customers. The BSC is one of the most widely recognised performance measurement systems (Neely *et al*., 2000), and is the most widely applied in facilities management (Toni *et al*., 2007). The four perspectives of the BSC have been commended by many for driving overall performance in organisations. Therefore, this research draws on the strengths of the BSC perspectives in the development of a performance measurement tool that considers the financial and non-financial measures in healthcare maintenance in IC.

Insert Table 1

2.2 Step 2: Ranking the CSFs according to their importance in IC

In the second stage of the research process, the different levels of importance of the CSFs and performance measures were established, as they were categorised into different mean zones. In establishing the levels of importance of the CSFs and performance measures, a three-round Delphi study was applied. The Delphi study has been accepted for publication in the International Journal of Health care Quality Assurance under the title 'Key performance measures to control maintenance-associated HAIs', Volume, 28; Issue, 7. The Delphi participants were purposively selected across Acute NHS Trusts in England. For people to be considered as Delphi participants, they needed to have extensive healthcare maintenance and IC experience and knowledge, and to have occupied healthcare maintenance manager or IC team member positions (i.e., as IC doctors, nurses or microbiologists) in an acute NHS trust for at least five years. In addition, it was a requirement that participation in the Delphi study was not to be delegated to someone else.

The CSFs and performance measures identified in the first process (literature review) were used to design the Round 1 Delphi instrument. In the first round of the Delphi exercise, the participants were presented with the CSFs and performance measures identified in the literature and given the task of identifying new ones. The first round Delphi exercise results were then used to modify the second round Delphi instrument. Delphi participants provided comments and suggestions that led to re-wording and in some instances re-structuring sections. The Round 1 Delphi results were analysed manually. In total, 11 new performance measures were identified in the first round of the Delphi exercise. These are italicised in Table I.

In the second round, participants were asked to rate 67 performance measures. The rating was based on a four-point Likert scale, where scales 1 and 2 (‘very important’ and ‘important’) represented the positive category, and scales 3 and 4 (‘unimportant’ and ‘very unimportant’) the negative category. The results of the Round 2 Delphi exercise were inputted into the SPSS (version 21) statistical software, and analysed through descriptive statistics. The decision to retain a performance measure in any Delphi round required that both healthcare maintenance managers and IC members agreed. Therefore, for a performance measure to be retained in any round, the participants had to achieve a group mean score of 3.28 or above. Any performance measure with a group mean less than 3.28 was re-submitted to the Delphi participants for re-rating.

Between the second and third rounds of the Delphi exercise, healthcare maintenance managers and IC members identified 53 important performance measures in healthcare maintenance in IC. These are shown in Table 2 (columns D and E). The codes (C – 1 to C – 67) that are used for the performance measures in Table 2 (column C) correspond to the list of performance measures in Table 1. Although most studies of this nature traditionally end here, this research study did not. At this stage of the research, it appears as though all the performance measures with a high level of consensus have the same level of importance in IC. According to Lavy *et al*. (2010), this problem is caused by the fact that there are too many performance measures (or indicators) in facilities management. For example, in a study conducted by Hinks and McNay (2005), 172 performance measures were identified. In another example, the Delphi participants in a study on organisational readiness for clinical information technology/system innovation identified up to 316 performance measures (Snyder-Halpern, 2001). According to Tangen (2004), it costs organisations money and time to analyse too many performance measures. Too many performance measures may result in information overload. As the organisation grapples with many performance measures, it becomes difficult for them to prioritize.

As time is money, it is necessary for organisations to collect data only on meaningful CSFs and performance measures, i.e. those that offer important insights. One factor that may limit the benefits of such an exercise in facilities is the lack of a meaningful categorisation of CSFs and performance measures (Lavy *et al.*, 2010). In a few studies where some sort of categorisation has been applied, the level of importance of the CSFs under which the performance measures are categorised has not been established. This adds to the difficulty of selecting appropriate performance measures to drive performance in the organisation. This study therefore attempts to establish the level of importance of the CSFs in infection control. For this purpose, three steps were proposed:

1. *Categorisation of the performance measures into different mean zones*: Since the Delphi exercises were conducted on a four-point Likert scale, the mean zones were established by dividing the difference between the maximum and minimum level of consensuses by four (4 − 3.28/4). This produces four mean zones (I, II, III and IV) with intervals of approximately 0.18. These were then linked to the CSFs, which are categorised according to the four perspectives of the BSC. If the mean score of the performance measure is X, the mean zone it belongs to is identified using the following scale ≤ 3.82 to ≥ 4 (Mean Zone I), ≤3.64 to >3.82 (Mean Zone 2), ≤3.46 to >3.64 (Mean Zone 3), and ≤3.28 to >3.46 Mean Zone 4). All those performance measures with a mean score of less than 3.28 were categorised in a fifth mean zone and given a weight of zero. As shown in Table 2, there were 10 (14.9%) performance measures under mean zone 1, and 14 (20.8%) performance measures under mean zone V. The majority of important performance measures (54.8%) were categorised under mean zones III and IV.

2. *Assign weights to the mean zones:* The mean zones were given weighted scores of between 4 and 1, where 4 and 1 represent the highest and lowest mean scores respectively. In a number studies in fields such as education (Ohio Department of Education, 2007) and climate change (Emerson *et al.*, 2012) methodologies that are different from this one have been used to weight items. The weights have not been assigned according to mean zones. In education, for example, different performance levels ('untested students', 'below limited', 'basic', 'proficient', 'accelerated' and 'advanced') are assigned different weights. Performance is calculated by simply multiplying the number of students in a performance level by the weight and dividing the results by overall possible score. In this research, this has been achieved differently (refer to section 2.3).

3. *Establish the levels of importance of the CSFs:* The level of importance of the CSFs in IC was determined through a research technique called the weighted mean. The weighted mean is different from the mean in that some data points contribute more than others do. For every CSF, the number of performance measures categorised under the different mean zones were multiplied by the weighted score. These were then added, and divided by the total number of performance measures for that particular CSF to give its level of importance. The results of the CSFs according to their levels of importance in IC are presented in Table 2. So far, the most important CSFs in healthcare maintenance in IC are 'Liaison and Communication between the Healthcare Maintenance Department and IC Team', 'Infection Control Practices' (Cleaning and Administrative Requirements)', and 'Maintenance Resource Availability'. On the other hand, the least important CSFs are 'Customer Satisfaction', 'Transport Requirements', 'Staff Training', and 'Staff Development'.

The ranking of the performance measures 1 - 67 (column E, Table 2) indicates that some performance measures are more important than others are. For example, even though 'Liaison and Communication with the Infection Control Team' is the most important CSF, the performance measures (C – 1 to C – 6) have varying levels of important in healthcare maintenance in IC. The six measures achieved rankings of 1, 3, 13, 26, 46 and 46, and the range between the first and sixth performance measure is 45. Variations also exist in the level of importance of the performance measures under the eight different CSFs. Therefore, there is a need to develop a performance measurement tool (PMT) that enables healthcare maintenance managers to select the most important performance measures from the eight CSFs, in order to drive performance in IC. The PMT that has been developed in this research attempts to meet some of these needs.

INSERT TABLE 2

2.3 The Development of a PMT in healthcare maintenance in IC

As shown in Table 3, a performance measurement tool (PMT) was devised in this research to enable healthcare maintenance managers to quantify performance in IC. The PMT should enable healthcare maintenance managers to establish the level of performance against individual performance measures, as well as against a group of performance measures in a mean zone. Where there is more than one mean zone, the PMT allows healthcare maintenance managers to measure and compare the performance of all mean zones at the same time. Finally, through the application of the PMT, healthcare maintenance managers will be able state the level of performance of the healthcare maintenance department in IC. The PMT has to be used in conjunction with the results and categorisation of the performance measures achieved through the Delphi exercise (Table 2).

It is advised that the healthcare maintenance managers work closely with members of the infection control team for the selection of pertinent performance measures that will help drive the performance of the healthcare maintenance department in IC. Performance measures should be selected according to their level of importance in IC from all the four perspectives of the BSC. They should also be categorised according to the four mean zones of the PMT using the mean score results presented in Table 2. The fifth mean zone (see Table 2) contains unimportant performance measures. As shown in Table 3, the four mean zones of the PMT are coded WS_A, WS_B, WS_C and WS_D. These mean zones are also assigned weights of 4,3,2,1 respectively. For every selected performance measure, the healthcare maintenance manager at the end of the measurement exercise should state the result that is achieved on a scale of 1 – 5. In doing so, they must take into account the interpretation given to the rating scale. The rating scale (L) that is proposed in this research ranges from very poor to excellent (1 – 'very poor', 2 – 'poor', 3 – 'average', 4 – 'good', 5 – 'excellent'). Conversely, the scale for interpreting the results of the PMT ranges from poor to excellent (≥ 1% to < 25% - 'very poor', ≥ 25% to < 50% - 'average', ≥ 50% - < 75% - 'good', ≥ 75% - ≤ 100% - 'excellent').

Since the performance measures have varying levels of importance in IC, it is important to consider the weights. Therefore, the weighted score (WS) for each performance measure is calculated by multiplying the achieved level of performance (L) against the assigned weight (W). However, the performance on individual performance measures can be calculated simply by dividing the assigned level of performance (L) by 5 – the maximum level of performance for a performance measure. Since the results are presented in percentages, the result is then multiplied by a hundred. Information gathered about individual mean zones allows the healthcare maintenance manager to identify whether the objectives and targets of the healthcare maintenance department in IC are being met. The formula used to score individual performance measures in the PMT is given as:

$$\frac{(L)}{(5)} \times 100$$

Where:

L – Level of performance

INSERT TABLE 3

The PMT can also be applied to calculate the level of performance of performance measures in a mean zone, e.g. WS_A. The calculations presented in the column entitled ‘Performance Score 2’ (Table 3) take into account only the performance measures in one mean zone. Performance in a mean zone is calculated by first adding the weighted scores in the mean zone. The result is then divided by the total number of performance measures multiplied by the maximum weighted score for that mean zone and then multiplied by 100. As shown in Table 3, the performance of the mean zone WS_A is 66.6%. According to the classification developed in this research, the level of performance of the healthcare maintenance department is considered ‘good’. This however suggests scope for further improvement in the performance of the healthcare maintenance in IC. The results obtained for individual performance measures in a mean zone could be used to gauge areas for further improvement. The formula for calculating performance in a mean zone is given as:

$$\frac{(WS_1 + WS_2 + WS_3) \times 100}{N(P_A) \times (L \times W)}$$

Where:

WS_1, WS_2, WS_3 – Weighted score for individual performance measures

$N(P_A)$ – Number of performance measures in a mean zone

$(L \times W)$ – Maximum weighted score for a performance measure

Where there is more than one mean zone, the performance of a mean zone is calculated by taking into account all the performance measures of the other mean zones. This allows healthcare maintenance managers to compare performance across different mean zones. It also indicates where resources and effort should be directed. As shown in Table 3, when the mean zones are aggregated, the level of performance of the mean zones falls. This is because the weights of the different performance measures are factored into the calculations. The PMT also allows the healthcare maintenance manager to estimate the overall performance of the healthcare maintenance department in IC. To calculate 'performance score 3' (in Table 3), the first step is to add the weighted scores of the performance measures in any of the mean zones (i.e. (WS_1 +WS_2 +WS_3)). This is then divided by the total number of performance measures in the mean zones, multiplied by their respective maximum weighted scores. The final score is again multiplied by 100. In the example provided, the performance of mean zones WS_A, WS_B, WS_C and WS_D are 30.77%, 16.15%, 15.38% and 3.08% respectively. The formula for calculating performance in more than one mean zone is:

$$\frac{\Sigma\,(WS_A)}{\Sigma\,(WS_A + WS_B + WS_C + WS_D)} \times 100$$

Where:

Σ – Sum

WS_A – Weighted score of mean zone 'A'

WS_B – Weighted score of mean zone 'B'

WS_C – Weighted score of mean zone 'C'

WS_D - Weighted score of mean zone 'D'

To improve on the result of the mean zones, managers have to improve in the performance of individual performance measures in the mean zone. Assuming that the three performance measures in WS_A achieved 100%, the performance of WS_A will be 46.1%. Similarly, those for WS_B, WS_C and WS_D will be 23.1%, 23.07% and 7.7% respectively (totalling 100%). The above figures clearly show that emphasis is on the most critical performance measures. Only three out of the ten performance measures in the PMT are categorised in the mean zone WS_A. Notwithstanding, they account for 46.1% of the overall performance score. The overall performance score for WS_B and WS_C are similar, though fewer performance measures were selected for WS_B.

The overall performance of the healthcare maintenance department in IC is calculated by simply adding the percentage scores of the four mean zones (performance score 3 in Table 3). In the example provided, the performance of the healthcare maintenance is 65.38%. This can also be calculated by dividing the total weighted scores (WS_1 - WS10) by the total number of performance measures in the mean zones multiplied by the respective maximum weighted scores. This is multiplied by 100. In the example provided in Table 3, the total achieved weighed scores for all four mean zones are 85. Conversely, the maximum weighted score for all the four mean zones are WS_A (3 × 20) + WS_B (2 ×15) + WS_C (3 ×10) + WS_D (2 ×5) = 130.

$$\frac{\Sigma\,(WS_A + WS_B + WS_C + WS_D)}{\Sigma\,[N\,(P_A) \times 20] + [N\,(P_B) \times 15) + [N\,(P_C) \times 10] + [N\,(P_D) \times 5]} \text{ X } 100$$

$85/130 \times 100 = 65.38\%$

Where:

Σ – Sum

WS_A, WS_B, WS_C, WS_D - Weighted score of the mean zones

N (P_A) – Number of performance measures in mean zone ‘A’

N (P_B) – Number of performance measures in mean zone ‘B’

N (P_C) – Number of performance measures in mean zone ‘C’

N (P_D) – Number of performance measures in mean zone ‘D’

Relying on the scale applied in the PMT, the performance of the healthcare maintenance department in IC in this example is interpreted as good. Yet poor performance is clearly indicated against some of the performance measures. The results of ‘performance score 1’ indicate those performance measures with poor performance in IC. This information can be used by the healthcare maintenance manager to focus attention on the most crucial performance measures in IC (i.e. those with a weighted score of 4). Conversely, the information can also be used to replace those performance measures that have achieved a 100% score in IC. The formula provided above can also be used to benchmark the performance of healthcare maintenance departments in IC across the NHS.

3. Conclusion

This research has demonstrated how the results achieved from a Delphi study can be further analysed to direct resources, time and effort to the most critical CSFs and performance measures in healthcare maintenance in IC. The performance measures identified in the Delphi study were categorised into five mean zones. By assigning weights to the mean zones, it was possible to distinguish between the eight CSFs according to levels of importance in IC. Through the application of a statistical method called the weighted mean, ‘Liaison and Communication with the IC Team’ emerged as the most important CSF in healthcare maintenance in IC. The second most important CSF identified was ‘Infection Control Practices’. Of the three sub-groups under ‘Infection Control Practices’, ‘Cleaning Requirements’ attained the best result in IC. Although ‘Customer Satisfaction’ and ‘Maintenance Strategies’ ranked bottom, they also contained performance measures that were ranked highly in IC.

The five mean zones provide clarity about the level of importance of the performance measures in healthcare maintenance in IC. Since the CSFs and performance measures are also selected from the four areas of the BSC, performance is driven from all the critical areas of the healthcare maintenance department in IC. This of course is one of the key strengths of the PMT: the selection of performance measures from eight CSFs that have been categorised into the four perspectives of the BSC: internal business processes, financial, innovation, learning and customer satisfaction perspectives.

Through the application of the PMT, healthcare maintenance managers are able to measure performance in three levels. In each of these performance levels, performance measurement is driven by the weightings of the performance measures. Healthcare maintenance manager are thus able to verify whether poor results are coming from the most important or least important performance measures. Since the PMT allows healthcare maintenance managers to gather information about individual performance measures, resources and effort can easily be prioritised. The PMT that has been developed here could be used to benchmark healthcare maintenance services across NHS hospitals. Obviously, issues related to the healthcare maintenance strategy, mission, goals, objectives, targets, etc. will have to be addressed by individual healthcare maintenance departments. Having identified the CSFs and performance measures through expert opinion, the next challenge will be to test and validate the PMT across healthcare maintenance departments in the NHS.

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